

# **Improving Temperature Stability of Experiment Hutches**

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Theme: Beamline End stations

## **Abstract:**

Many 3<sup>rd</sup> generation light sources have beamlines which are capable of producing beam sizes of a few microns. Further developments in X ray optics are also allowing beams to be focused down to below 100nm. With such small beam sizes, intensities can be very low and long integration times are required. The stability of the position of the X-ray beam on the sample over periods of time of many hours or even days is critical. It is therefore important to reduce the effect of thermal expansion by using lower thermal expansion materials or improving temperature stability.

On new nano-focus beamlines the cost of expensive high stability ventilation systems can be justified, but there are many existing beamlines operating between 10 $\mu$ m and 500nm where improved temperature stabilization would be of benefit but expensive refurbishment is not justified.

This paper describes the work on an existing beamline at Diamond to improve temperature stability by improving the tuning of the air conditioning PID control system and changing from fluorescent to LED Lighting. The PID tuning method is described; the results during actual operations and the effects of LED lighting on stability are presented.

## **1-Data acquisition**

In many cases the hutch air conditioning system is tested after installation but its performance is not monitored and if it is monitored, this information may not be easily accessed by the beamline scientists. To improve understanding of the system and improve temperature stability the first stage is to collect information. On Beamline B16 we installed permanent PT100 sensors from which data is recorded and archived. At the start we used standard 0.1°C resolution cards but these were soon changed to higher resolution (0.01°C) interface cards. Sensors were located inside the two air conditioning ducts, one where the room sensor was located and three near where nano focus experiments are conducted. This has enabled a better understanding of what affects temperature stability and how by simple actions this can be improved. This includes the following;

Keeping the hutch doors closed wherever possible,

Reducing lighting level changes as much as possible,  
Allowing sufficient time for temperature equalization when experimental equipment is installed,  
Moving the room temperature sensor that controls the air chiller from a wall to the area where the most temperature critical components are located.

## 2-PID Tuning

The control unit used for many of the beamlines at Diamond is a Siemens Synco 200 universal controller. This operates in cascade mode with a PI+PID loop. The Siemens unit controls a motorized valve which regulates chilled water to two fan coil units located in the ceiling of the experiments hutch. Fig 1 is a schematic of the control system.

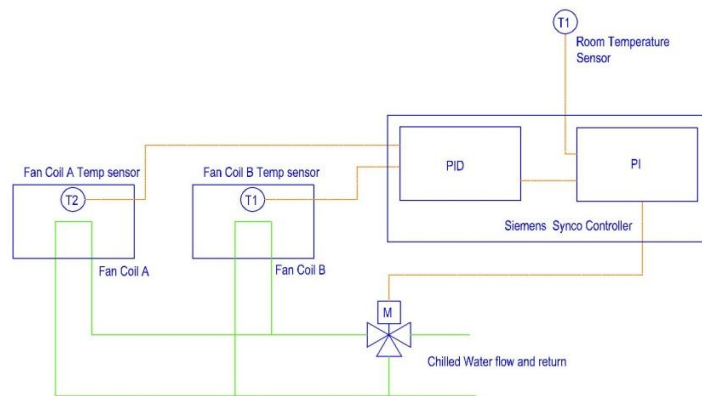


Fig 1 – Experiments hutch temperature control system

The settings were input by the system installer and it had been assumed that the temperature was well controlled. However, once data on temperatures had been collected it was found that the system was badly oscillating around the set point as shown in Fig 2.

Tuning was carried out by first disabling the cascade PI loop and only using the PID loop that controlled the output air temperature using feedback from the output air sensor. The Integration was set to zero and the gain was increased until oscillation occurred after a step input. The critical gain and time period were then used to calculate settings for the Proportional, Integral and Differential factors based upon Ziegler-Nichols or Tyreus-Luyben formulae. The best setting was found to be a slightly less aggressive proportional factor than that suggested by Tyreus-Luyben. Once this had been optimized the cascade control was re-connected and tuning of the PI parameters carried out. The results are shown in Fig 3.

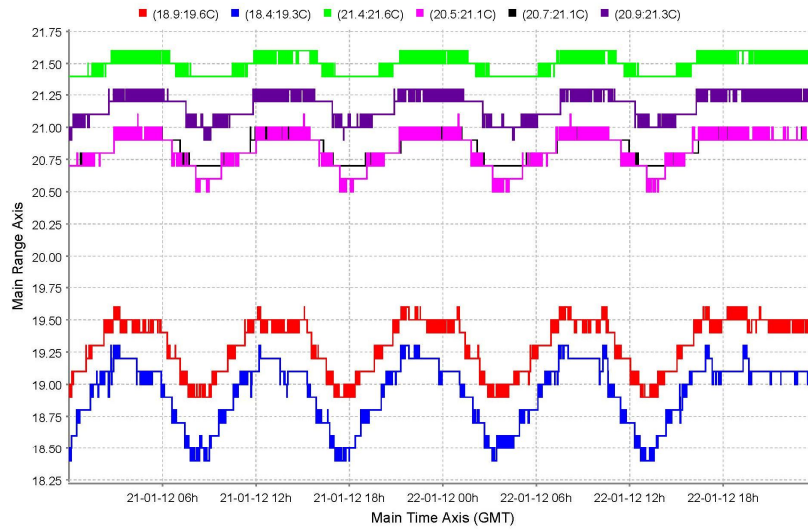


Fig 2 – Temperature results before tuning showing oscillating system.

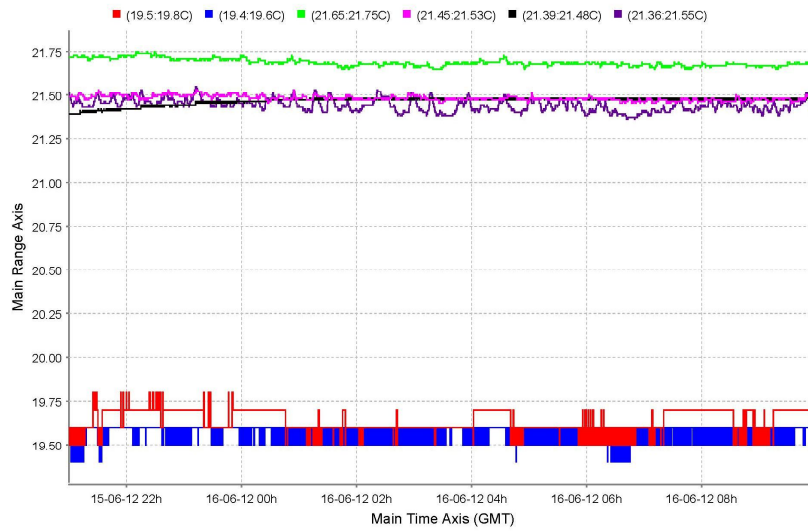


Fig 3 – Temperatures after tuning

Now it is found that peak to peak values of air temperatures during a 6 hour experiment of 0.15°C are easily achieved.

## **2-LED Lighting**

Maintaining highly stable temperature conditions are not helped by substantial changes in heat load. Lighting levels are one area where changes occur frequently and these lights output a substantial heat load. A typical hutch at Diamond Light Source includes blue lights, emergency back-up lights and an array of high level fluorescent tubes sufficient to give excellent illumination for experiment set up. Users often wish the experiment to be conducted with no ambient light and so lighting conditions fluctuate and the frequency of lighting changes depends upon the type of experiment.

Typically the temperature within an experiment hutch is controlled by a single room temperature sensor. When the lights are switched on the heat load into the room increases and so the fan coil chiller has to work harder to maintain the temperature at the room sensor location. The output air from the chiller is therefore colder and so parts of the hutch become colder. So, even if the hutch temperature at the room sensor location is maintained at a constant temperature other parts of the hutch will become hotter or colder as the lighting level changes.

Reducing the heat output from lights could improve the overall temperature stability within the hutch. On B16 Test Beamline we have been testing out LED lights. These LED lights consist of 1800mm long tubes within which are mounted a series of LED elements. They are supplied by 240V AC and so can directly replace the existing 1800mm fluorescent tubes using the same housings and diffusers.

B16 Test beamline was originally fitted with 16 off housings each containing 2 off T8,(6ft) 1800mm Long fluorescent tubes rated at 70Watts each. These are being replaced with LED tubes rated at 28W each. This gives a reduction in heat load from 2.2kW to 0.896kW.



Figure 4 –Photo of LED tubes

The beam of light from the LED tubes is narrower than the fluorescent tube so a greater portion of light is directed to the working area. We have used the beamline with a mixture of LED and fluorescent and users have expressed no concerns over the light pattern or colour rendition of the LED tubes. We have tried the LED lights with diffusers fitted and not fitted and in fact find the tubes alone give good even lighting with no glare.

Surface temperatures are much lower with the surface of the diffusers on a fluorescent tube being about 28.5° C whilst the LED surface is about 24.5°C. Figure 2 shows a temperature plot over 24 hours. The black line shows the temperature of the surface of a fluorescent light diffuser. The red and blue lines are the temperatures of the air at the outlet of the 2 fan coil chillers. The graph shows the reduced temperature of the air when the lights are ON and greater cooling is required.

Lighting condition	Fan coil 1 Outlet temperature ( °C)	Fan coil 2 outlet temperature ( °C)
6 LED + 4 Fluorescent	19.5 -19.6	19.7-19.8
6 LED + 12 Fluorescent	16.7- 16.8	17.0-17.2
16 Fluorescent	16.9 -17.1	15.7-15.8

Figure 5- Temperature comparison between different lighting conditions.

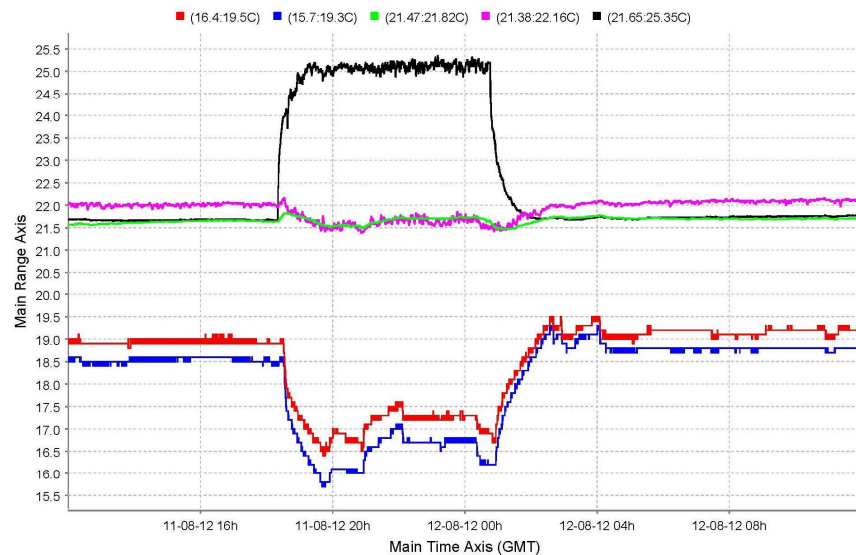


Figure 6- Temperature comparison between lights ON and OFF

Our conclusion so far is that replacing standard fluorescent tubes with LED lights does not affect the users experience of the beamline but it does reduce the temperature fluctuations when switching lighting conditions. Temperature stability over 24 hours is improved with all lights off, this may be due to non constant air currents generated by the hot lighting units.

The next stage is to replace all the standard lights with LED tubes. The Electrical supply to the emergency lights is being investigated.

#### **4-Phase Change materials**

Phase change materials are being used as part of energy recovery systems in air conditioning plants. There are a variety of materials based upon salts, fatty acids and paraffins . These phase change materials use the high latent heat to absorb thermal energy which is typically 50 times the heat capacity absorbed over 1°C. Most phase change materials change phase over a relatively wide temperature range but a pure paraffin has a well defined melting and solidifying temperature. N-Heptadecane ( $C_{17}H_{36}$ ) has a melting point of 22°C and could be used to provide a thermal stabilization medium for temperature critical experiments. Some experiments are ongoing with this material.

#### **5-Conclusion**

As the requirements for beam stability become more challenging temperature stability is becoming more important. The paper outlines a number of suggestions where temperature stability can be improved without substantial cost. These suggestions are as follows

- a) Collect data at 0.01°C resolution, archive and allow easy access by anyone.
- b) Analyse data and if required tune PID loops.
- c) Encourage a policy of doors to be kept closed whenever possible.
- d) Reduce heat load variations in beamlines by operating with constant lighting levels or reduced power consumption LED systems where lighting levels need to change.